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A Technique for Estimating the Impact of Improvements in Drug Testing Sensitivity on Detection and Deterrence of Illicit Drug Use by Navy Personnel

Jules I. Borack

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Reviewed by
Dennis Schurmeier

Approved and released by
Murray W. Rowe
Technical Director

Navy Personnel Research and Development Center
53335 Ryne Road
San Diego, California 92152-7250

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Jules I. Borack

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Navy Personnel Research and Development Center
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A model was developed for estimating the impact of improvements in drug testing sensitivity on both detecting and deterring illicit drug users. The model represents an improvement over existing detection and deterrence models by incorporating test rate and sensitivity parameters into estimation of the deterrence effect. The monthly test rate, sensitivity of the test to previous drug use, frequency of drug use, and other factors all impact the probability of detecting and deterring drug users. Improvements in drug test sensitivity were shown to have a dramatic impact on both detection and deterrence of illicit drug users.

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Foreword

This report was prepared as part of the In-House Independent Laboratory Research Program task (Program Element 0601152N, Project R0001, Work Unit 0601152N.R0001.17) 'Techniques for Linking Effectiveness and Time Dependencies into A Conceptual Model of Drug Testing'. The objective of this task is to develop a conceptual framework for linking the concepts of testing accuracy, deterrence and detection relevant to a urinalysis testing program. This effort provides a framework which extends and integrates methodologies for measuring detection and deterrence developed as part of the Statistical Methods for Drug Testing project (Program Element 0305889N, Work Unit 0305889N.R2143DR001) sponsored by the Chief of Naval Personnel (PERS-63).

The author wishes to thank Mark Chipman for his assistance in the development of this manuscript and Murray Rowe for his continuing support of this effort. The author also wishes to thank Dr. David Blank of PERS-63 for his leadership and dedication to Navy drug demand reduction research and development.

W. M. KEENEY
Commanding Officer

Summary

Background

The Navy's zero tolerance drug policy has been in effect since 1981. Since then the Navy has pursued an aggressive urinalysis testing program. The objectives of this testing program have been to deter and detect drug abuse, as well as provide data on the prevalence of drug abuse. All uniformed personnel are subject to random and other forms of urinalysis testing on a continuing basis. The current policy (Chief of Naval Operations, 1994) includes the following:

1. Random urinalysis with 10 to 30 percent of a unit's personnel tested monthly at the direction of unit commanders without permission of higher headquarters.

2. More than 30 percent testing with permission of higher headquarters.

3. "Unit sweeps" of all personnel in the unit.

4. "Probable cause" urinalysis for specific incidents.

The program has been considered successful; the proportion of sampled service members testing positive for drugs has fallen from approximately 7 percent in 1983 to less than 1 percent in recent years. Responses from surveys of Navy personnel (Bray et. al., 1995, 1992, 1989, 1986, 1983; Burt et. al., 1980) parallel this decline. In 1980, approximately 33 percent of Navy personnel indicated they had used illicit drugs during the past 30 days; this had declined to less than 4 percent in 1995. Drug use percentages reported in surveys are expected to be of greater magnitude than positive test results since only a fraction of users are detected. Because of the effects of drug abuse on readiness, health, and safety, it is important that the Navy continue to evaluate and improve its drug testing program and seek to develop an optimal drug testing strategy.

Borack and Mehay (1996) developed a conceptual model for determining an optimal drug testing program. The model integrated the concepts of deterrence, detection, and the cost of drug abuse to describe a process which generates costs and savings due to testing.

Objective

The objectives of this research were to (1) extend the model developed in Borack & Mehay (1996) to link improvements in urinalysis test sensitivity to changes in deterrence and detection of Navy illicit drug users and (2) estimate the deterrence and detection effects of tests of alternative sensitivity.

Methodology

The conceptual model of Borack and Mehay (1996) provided the framework for estimating the detection effect of drug testing for alternative values of test sensitivity. Inputs to the model include current enlisted and officer inventories, the proportion of demographically comparable

civilians who used illicit drugs during a 30-day period and test sensitivity. Sensitivity was defined as the probability of detecting a drug user if the user is selected for testing. A baseline case of test sensitivity assumed that detection within two days of drug use was certain, but detection would not occur beyond two days. Tests with double this sensitivity such that detection occurs within four days of drug use, or lower sensitivity where detection within two days occurs only 50 percent of the time, were also studied. Deterrence was estimated as a function of the probability of detection of a user. Simply put, the higher the probability of detection, the greater is the deterrence effect. Since the probability of detection depends on the frequency and type of drug used, monthly test rate and related test policies, and the sensitivity of the test, it follows that these factors influence not only the probability of detection but also the magnitude of the deterrence effect.

Results and Conclusions

The sensitivity of drug tests strongly affected both the estimated probability of detection and the deterrence effect of testing. Compared to the baseline case, drug tests which double the period of detection not only increase the probability of detection of a typical drug user by approximately one-third, but also deter an additional 9 percent of drug users. Borack & Mehay (1996) estimated the pool of potential Navy drug users to be approximately 40,000 individuals. Thus, testing at a 20 percent monthly test rate with baseline sensitivity can result in deterrence of approximately 22,800 users and an annual total impact (deterrence + detection) of 30,400. Doubling test effectiveness could deter 26,400 individuals and deter or detect 33,760 individuals; while decreasing test effectiveness by 50 percent could lower deterrence to 16,000 and diminish the annual total effect to 22,160 users. The model suggests that a test with baseline sensitivity administered to 20 percent of personnel monthly detects and deters users with approximately the same effectiveness as a test with double this test sensitivity administered to only 15 percent of personnel monthly. Similarly, a test with baseline sensitivity administered to 20 percent of personnel monthly detects and deters users with approximately the same effectiveness as a test that is 50 percent less sensitive which is administered to 40 percent of personnel monthly. Thus, there are profound tradeoffs between test sensitivity and test rate. Improvements in test sensitivity can greatly impact the effectiveness of a urinalysis testing program.

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Introduction

The Navy's zero tolerance drug policy has been in effect since 1981. Since then the Navy has pursued an aggressive urinalysis testing program. The objectives of this testing program have been to deter and detect drug abuse, as well as provide data on the prevalence of drug abuse. All uniformed personnel are subject to random and other urinalysis testing on a continuing basis. The current policy (Chief of Naval Operations, 1994) includes the following:

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Borack and Mehay (1996) developed a conceptual model for determining an optimal drug testing program. The model integrated the concepts of deterrence, detection and cost of drug abuse to establish a process for determining the relationship between the costs and benefits of drug testing. Figure 1 reproduces the conceptual model. Deterrence is assumed to occur first; undeterred users are then subject to detection. The productivity loss (or equivalently, lower value) of undetected and undeterred users represents the cost of drug use to the Navy. This cost can be compared to productivity loss that would occur if no testing were conducted in order to estimate the savings that result from drug testing. The cost of testing includes laboratory testing costs, the time required to participate in testing, and, optionally, the cost of replacing detected personnel. These costs can be compared to savings in order to estimate the net benefits of drug testing. Mathematical expressions were developed which estimated the proportion of individuals detected (Borack 1996a, 1996b, 1997) based on alternative monthly test rates. Based on the conceptual model, Borack (1996c) estimated the deterrence effect of testing. The deterrence effect was defined as the percentage decline in drug use from that which would occur if no testing were conducted. Figure 2 graphs the deterrence effect as a function of the monthly test rate. The function exhibits a classic diminishing returns pattern--higher levels of testing increase deterrence but at a decreasing rate. Borack and Mehay (1996) estimated that Navy drug use would be somewhat lower (approximately 9%) than corresponding civilian use even if there

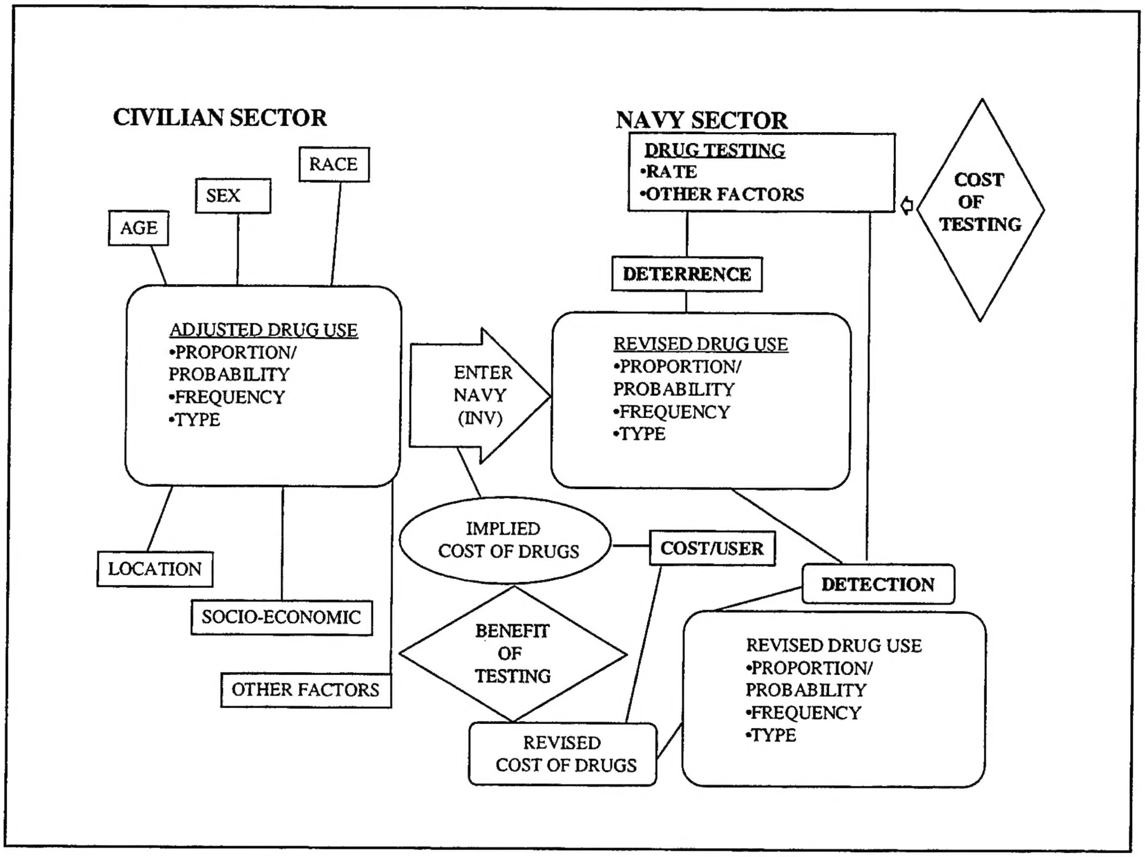

Figure 1. Conceptual model.

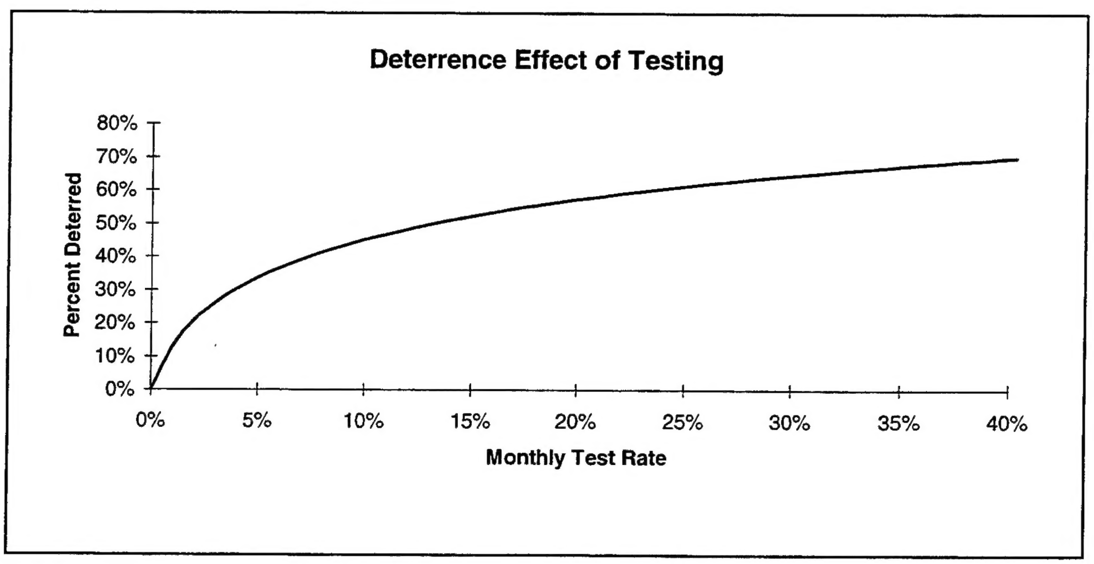

Figure 2. Deterrence effect of testing at alternative monthly rates.

Objective

The objectives of this research were to (1) extend the model developed by Borack and Mehay to link improvements in urinalysis test sensitivity to the detection and deterrence of Navy illicit drug users and (2) estimate the deterrence and detection effects of tests of alternative sensitivity.

Methodology

We define drug test sensitivity as the probability of obtaining a positive test result given the individual used illicit drugs; that is, *Sensitivity = P(Positive test result | Individual used illicit drugs).* Borack and Mehay (1996) estimated monthly and annual probabilities of detection based on patterns of drug use from the 1992 Worldwide Survey of Substance Abuse and Health Behaviors Among Military Personnel (Bray, et al., 1992). These probabilities assumed that the vector of test sensitivity, ***S***, was as follows: ***S*** = (1,1,0,0,...,0) where the i^{th} element represents the sensitivity of the test to drug use between i-1 and i days prior to testing. According to ***S***, drugs will be detected with certainty on the first and second day after use, but will not be detected beyond the second day. In general, we assume that elements of ***S*** are monotonically non-increasing, that is, as time elapses since drug use, detection probabilities decline or remain the same. Figures 3 and 4 graphically depict these probabilities. The probability of detection during a month is approximately linearly related to the monthly test rate while the probability of detection during a year exhibits diminishing returns. In order to escape detection during a year, an individual must remain undetected in each of its twelve months.

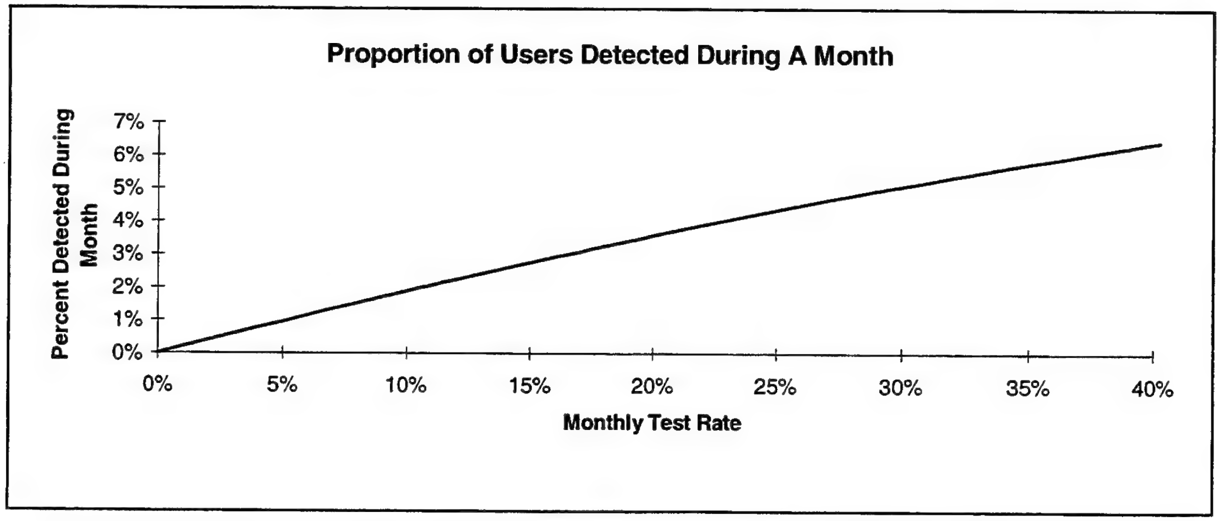

Figure 3. Probability of detection during a month as a function of the monthly test rate.

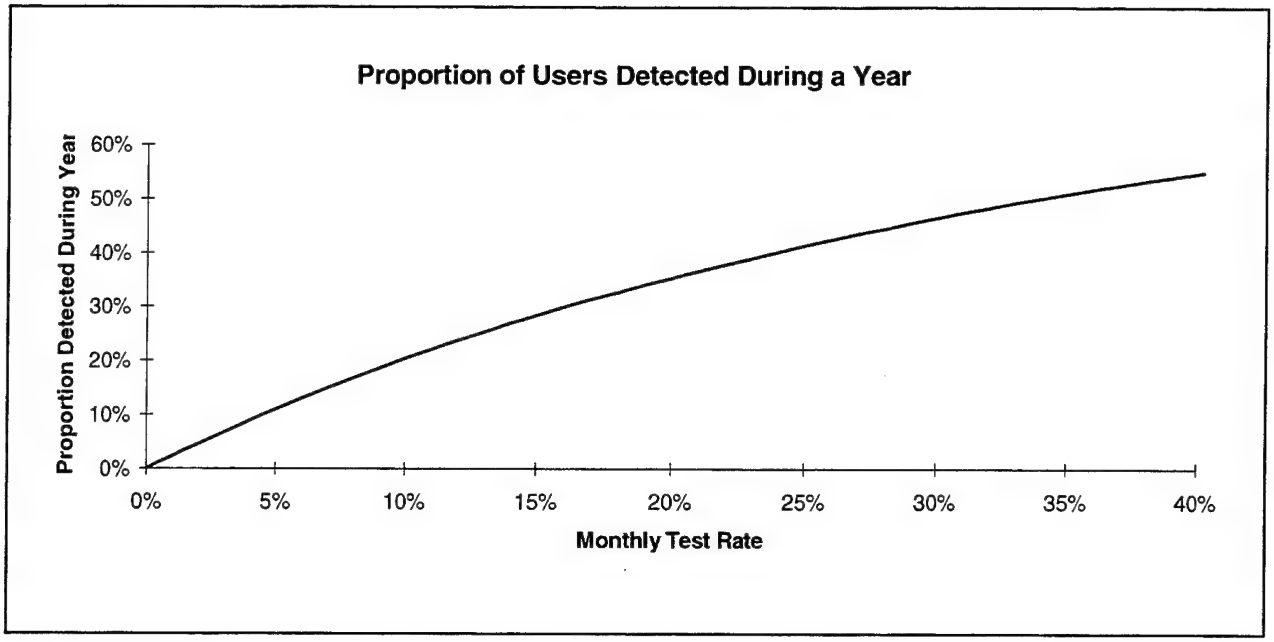

Figure 4. Proportion of users detected during a year as a function of the monthly test rate.

Estimation of the Deterrence and Detection Effects of Testing

In order to estimate the deterrence effect of testing, Borack (1996c) estimated the proportion of personnel who would use drugs and the frequency of their drug use in the absence of testing. Let $\eta_{30,0}$ represent the proportion of Navy personnel who would use drugs at least once during a 30-day period in the absence of drug testing. Estimates of $\eta_{30,0}$ were constructed for 1980, 1982, 1985, 1988, 1992, and 1995 by demographically adjusting data from civilian surveys of drug use (Burt, et al., 1980) (Bray, et al.,1983; 1986; 1989; 1992; 1995). Estimates of $\eta_{30,p}$, the proportion of Navy personnel using drugs at least once during a 30-day period if the monthly test rate were p, were obtained directly from corresponding year surveys of drug use among military personnel (WWS) (Burt, et al., 1980) (Bray, et al.,1983; 1986; 1989; 1992; 1995), and are presented in Table 1. The column headed r represents the ratio of the number of laboratory tests to the corresponding annual inventory; the column headed p represents the corresponding average proportion tested during a month (monthly test rate).

Table 1

Estimates of $\eta_{30,0}$ and $\eta_{30,p}$ for Fiscal Years 80, 82, 85, 88, 92, and 95

Fiscal Year	$\eta_{30,0}$	$\eta_{30,p}$	r	p
80	.363	.330	0.000	0.000
82	.270	.162	0.725	0.060
85	.244	.103	2.442	0.204
88	.150	.054	2.562	0.214
92	.105	.040	2.518	0.210
95	.100	.037	2.309	0.185

In order to estimate the relationship between the underlying test rate, p, and the deterrence effect, a logarithmic regression model was fit to the percentage difference *(PDIFF)* between $\eta_{30,0}$ (i.e., the proportion of drug users among an equivalent group of civilians) and $\eta_{30,p}$ as a function of the logarithm of p, yielding the following parameter estimates:

$$PDIFF(p) = .878 + .172\ln(p)$$

The value of p was scaled upward by one unit to avoid zero values. The corresponding values of adjusted R^2 and F were .986 and 341.79, respectively, which were both highly significant. In order to estimate the deterrence effect of testing, $DETER(p) = \dfrac{PDIFF(p) - PDIFF(0)}{1 - PDIFF(0)}$ was computed. *DETER(p)* represents the percentage difference between testing at rate p and not testing at all (i.e., testing at rate 0). Figure 2 graphically depicts this relationship. This function assumed that the test rate was the sole variable in estimating the deterrence effect of urinalysis testing. In this report, we assume that the test rate is not the only factor in deterring drug use. Instead, we assume the deterrence effect of testing is related to the probability of detection which is, in part, determined by the test rate. In summary, we assume the greater the ability of a testing procedure to detect a drug user, the greater will be its impact on deterrence.

As noted above, Borack and Mehay estimated monthly and annual probabilities of detection based on patterns of drug use from the 1992 Worldwide Survey of Substance Abuse and Health Behaviors Among Military Personnel (Bray, et al., 1992). Borack (1996a, 1996b) developed mathematical relationships for estimating the probabilities of detecting non-gaming and gaming drug users based on specific patterns of drug use and testing patterns. Non-gaming users were defined as individuals who choose their days of drug use without consideration of when testing might occur, while gaming users alter their drug use based on anticipated patterns of drug testing. Borack (1996a) shows that the probability of detecting a non-gaming drug user, *P(DET)* is:

$$P(DET) = 1 - \left(1 - \frac{m_r}{k}(\alpha)\right)^k \qquad (1)$$

where m_r is the monthly test rate (e.g., 20%), k is the number of test days during the month, and α is the probability of testing positive if selected for testing (which depends on the pattern of drug use and sensitivity of the test). Equations for estimating α were also derived. For small values of $\frac{m_r}{k}$, $\left(1-\frac{m_r}{k}(\alpha)\right)^k \cong 1-m_r(\alpha)$. Therefore, for small values of $\frac{m_r}{k}$,

$$P(DET) \cong m_r(\alpha) \tag{2}$$

Borack (1996b) derived a methodology for estimating the probability of detecting gaming drug users. Based on the relative proportion of gaming and non-gaming users who use drugs a specific number of days per month, Borack and Mehay estimated the overall probability of detection as:

$$P(\hat{DET}_p) \cong .244p - .0417p^2 \tag{3}$$

where p represents the monthly test rate. Note that the probability of remaining undetected for the year is $(1-P(\hat{DET}_p))^{12}$; therefore, the probability of detection during a year is $1-(1-P(\hat{DET}_p))^{12}$. Equation (3) assumed $S = (1,1,0,0,\ldots,0)$. Table 2 lists the relative proportion of gaming and non-gaming users who use drugs a specific number of days per month as derived from Bray et. al., 1992 (see Borack & Mehay for further discussion). Assuming these relative proportions are consistent throughout the estimation period, Table 3 provides estimates of the probability of detection, $P(\hat{DET}_p)$, based on overall average monthly test rates. Table 3 also reproduces $\eta_{30.0}$ and $\eta_{30.p}$ from Table 1.

Table 2

Percentage of Navy Drug Users During the Past 30 Days by Frequency of Use and Gaming Strategy

	Frequency of Use (Days During Month}									
	Gaming User					Non-Gaming User				
	1-3	**4-10**	**11-19**	**20-27**	**28-30**	**1-3**	**4-10**	**11-19**	**20-27**	**28-30**
Percent of Users	40.93	20.86	3.56	2.48	0.00	21.13	1.13	8.31	0.00	1.60

Source: Worldwide Survey of Substance Abuse and Health Behaviors Among Military Personnel, 1992.

Table 3

Estimates of $\eta_{30,0}$, $\eta_{30,p}$, and $P(\hat{DET}_p)$, for Fiscal Years 80, 82, 85, 88, 92, and 95

Fiscal Year	$\eta_{30,0}$	$\eta_{30,p}$	$P(\hat{DET}_p)$
80	.363	.330	.0000
82	.270	.162	.0146
85	.244	.103	.0479
88	.150	.054	.0502
92	.105	.040	.0494
95	.100	.037	.0437

In order to estimate the relationship between $P(\hat{DET}_p)$ and the deterrence effect, a logarithmic regression model was fit to the percentage difference *(PDIFF)* between $\eta_{30,0}$ (i.e., the proportion of drug users among a demographically equivalent group of civilians) and $\eta_{30,p}$ as a function of the logarithm of $P(\hat{DET}_p)$, yielding the following parameter estimates:

$$PDIFF(p) = 1.456 + .293 \ln(P(\hat{DET}_p)) \tag{4}$$

The values of $P(\hat{DET}_p)$ were scaled upward by .01 to avoid zero values. The corresponding values of adjusted R^2 and F were .979 and 228.832, respectively, which were both highly significant. In order to estimate the deterrence effect of testing, $DETER(p) = \dfrac{PDIFF(p) - PDIFF(0)}{1 - PDIFF(0)}$, was computed. Figure 5 graphically depicts this relationship. As expected, the function exhibits diminishing returns, that is, deterrence increases but at a decreasing rate as a function of the detection probability.

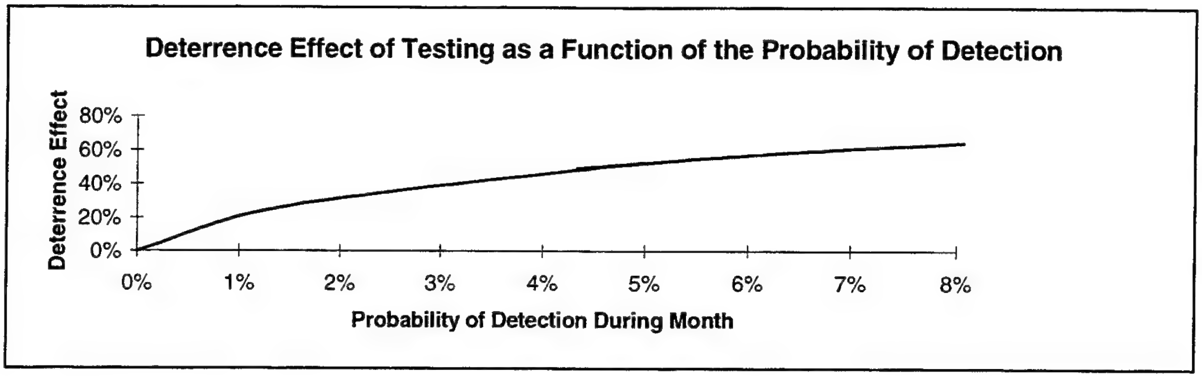

Figure 5. Deterrence effect of testing as a function of the probability of detection (during a month).

Estimation of the Deterrence Effects for Alternative Test Sensitivities

The deterrence effects presented in Figure 5 were based on S = (1,1,0,0,...,0). Suppose a new test with greater sensitivity is developed which doubles the length of time the drug is detectable, that is, S' (1,1,1,1,...,0). Alternatively, suppose a less sensitive test detects users during the original two-day time frame with only 50 percent probability, that is, S'' = (.5,.5,0,0,...,0). Under the same assumptions as discussed in the previous section, $P(\hat{DET}_p)$ can be computed for these test sensitivities for specific monthly test rates. Table 4 presents these estimates of $P(\hat{DET}_p)$ for various monthly test rates.

Table 4

Impact of Monthly Test Rate and Test Sensitivity on Detection

Monthly Test Rate (p)	Probability of Detection S	Probability of Detection S'	Probability of Detection S''
0.00	0.0000	0.0000	0.0000
0.05	0.0123	0.0167	0.0062
0.10	0.0242	0.0329	0.0122
0.15	0.0360	0.0488	0.0183
0.20	0.0474	0.0642	0.0242
0.25	0.0587	0.0793	0.0301
0.30	0.0697	0.0940	0.0359
0.40	0.0910	0.1224	0.0474
0.50	0.1115	0.1495	0.0586
0.60	0.1312	0.1754	0.0696
0.70	0.1502	0.2001	0.0803
0.80	0.1684	0.2238	0.0908
0.90	0.1859	0.2464	0.1011
1.00	0.2029	0.2681	0.1112

Fitting quadratic functions through the origin to the values obtained yields the following equations:

$$\text{For } S', \; P(\hat{DET}_p) \cong .332p - .0641p^2 \tag{5}$$

$$\text{For } S'', \; P(\hat{DET}_p) \cong .123p - .0122p^2 \tag{6}$$

Figure 6 graphically represents $P(\hat{DET}_p)$ for S, S', and S''. When compared to the baseline test, the probability of detection is discernibly higher for the more sensitive test and considerably lower for the less sensitive test.

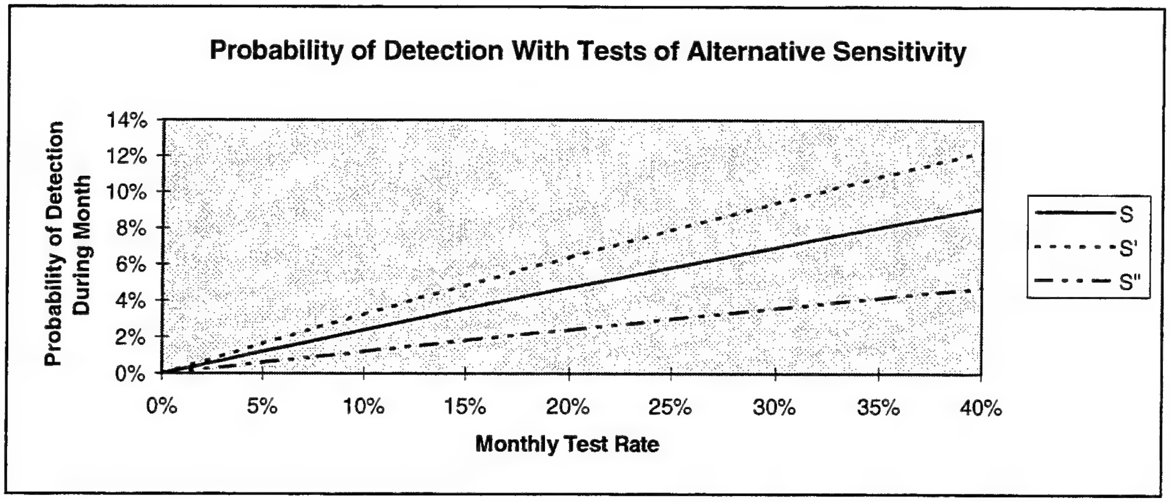

Figure 6. Probability of detection of average drug user with tests of alternative sensitivity.

The next section compares the deterrence effect of these three tests.

Results

Table 5 presents estimates of *DETER(p)* of tests with alternative sensitivity vectors, ***S***, ***S′***, and, ***S″*** as previously defined. Estimates of *DETER(p)* are based on the values of *PDIFF(p)* computed from equation (4). Test sensitivity exerts a profound impact on deterrence. The test with double sensitivity yields approximately the same deterrence at a 15 percent monthly test rate as the baseline test at a 20 percent monthly rate. The test with only half the sensitivity requires approximately a 40 percent monthly test rate to achieve comparable deterrence. Figure 7 graphically illustrates these comparisons.

Table 5

Impact of Monthly Test Rate and Test Sensitivity on Deterrence

Monthly Test Rate (*p*)	Proportion Deterred *S*	Proportion Deterred *S′*	Proportion Deterred *S″*
0.00	0.00	0.00	0.00
0.05	0.26	0.32	0.16
0.10	0.40	0.48	0.26
0.15	0.50	0.58	0.34
0.20	0.57	0.66	0.40
0.25	0.63	0.72	0.45
0.30	0.68	0.77	0.50
0.35	0.72	0.81	0.54
0.40	0.76	0.85	0.57

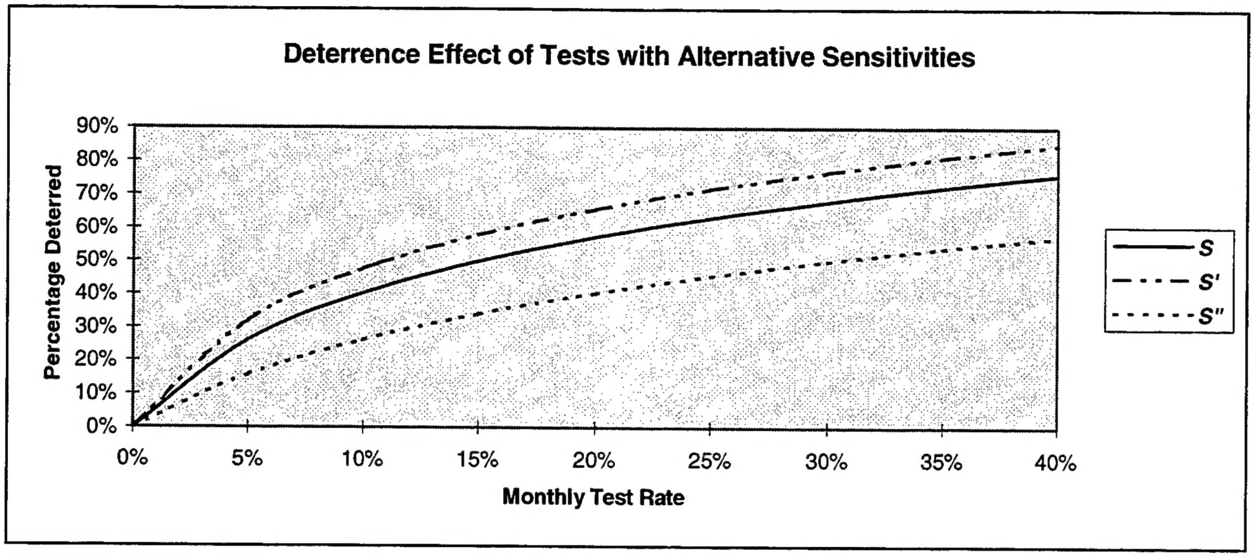

Figure 7. Deterrence effect of tests with alternative sensitivities.

Table 6 presents estimates per 1000 users of the number expected to be deterred or detected per month by selected combinations of test rate and test sensitivity. Table 6 was computed as $(DETER(p) + (1- DETER(p))^* P(\hat{DET}_p))^*1000$ which represents the sum of the number of users deterred and the number of undeterred users detected per month. Table 7 presents a corresponding estimate of users deterred or detected per year and provides an estimate of the annual impact of drug testing. As can be seen in Table 7, testing with baseline sensitivity at a 15 percent monthly test rate corresponds to testing with approximately half this sensitivity at 30 percent. Doubling test sensitivity yields similar results for a bit more than 10 percent, or roughly a 50 percent decrease in the test rate. Thus, test sensitivity strongly affects the test rate required to achieve specific levels of deterrence and detection.

Table 6

Number of Users Deterred or Detected in a Month (Per 1000 Users)

Monthly Test Rate (p)	S	S'	S''
0.00	0	0	0
0.05	269	330	162
0.10	416	492	270
0.15	516	599	352
0.20	592	678	417
0.25	652	739	471
0.30	702	789	517
0.35	744	831	557
0.40	780	866	592

Table 7

Number of Users Deterred or Detected Annually
(Per 1000 Users)

Monthly Test Rate (p)	S	S'	S''
0.00	0	0	0
0.05	361	442	216
0.10	553	647	362
0.15	675	768	470
0.20	760	844	554
0.25	821	895	622
0.30	865	929	677
0.35	898	952	722
0.40	923	968	761

Conclusions and Recommendations

The sensitivity of drug tests strongly affected both the estimated probability of detection and the deterrence effect of testing. Compared to the baseline case, drug tests which double the period of detection not only increase the probability of detection of a typical drug user by approximately 1/3, but also deter an additional 9 percent of drug users. Borack and Mehay (1996) estimated the pool of potential Navy drug users to be approximately 40,000 individuals. Thus, testing at a 20 percent monthly test rate with baseline sensitivity can result in deterrence of approximately 22,800 users and an annual total impact (deterrence + detection) of 30,400. Doubling test effectiveness could deter 26,400 individuals and deter or detect 33,760 individuals; while decreasing test effectiveness by 50 percent could lower deterrence to 16,000 and diminish the annual total effect to 22,160 users. The model suggests that a test with baseline sensitivity administered to 20 percent of personnel monthly detects and deters users with approximately the same effectiveness as a test with double this test sensitivity administered to only 15 percent of personnel monthly. Similarly, a test with baseline sensitivity administered to 20 percent of personnel monthly detects and deters users with approximately the same effectiveness as a test that is 50 percent less sensitive which is administered to 40 percent of personnel monthly. Thus, there are profound tradeoffs between test sensitivity and test rate. Improvements in test sensitivity can greatly impact the effectiveness of a urinalysis testing program.

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